GRAVITY DRILLING OF MASS DIFFERENTIATED PLANETS. L. V. Potts[1], T. Leftwich[2], H. R. Kim[2], S-H. Han[1], and R. R. B. von Frese[1,2], [1]Laboratory for Space Geodesy and Remote Sensing Research, The Ohio State University, 470 Hitchcock Hall, 2070 Neil Avenue, Columbus, OH 43210 (potts.3@osu.edu), [2]Dept. of Geological Sciences, The Ohio State University, 275 Mendenhall Laboratory, 125 S. Oval Mall, Columbus, OH 43210.

Summary: Analysis of satellite-measured gravity and topography can provide crust-to-core mass variation models for considering the geologic evolution of terrestrial planets. These mass differentiated models facilitate developing new perspectives on the poorly understood crustal and subcrustal features of the terrestrial planets.

Introduction: The internal structures of terrestrial planets are commonly constrained by seismic data and geochemical considerations. We suggest that these constraints may be augmented by gravity drilling that focuses on interpreting satellite altitude free-air gravity observations for boundary undulations of the internal density layers related to mass flow. This approach involves separating the free-air gravity anomalies into terrain-correlated and -decorrelated components based on the correlation spectrum between the anomalies and the gravity effects of the terrain [1].

The terrain decorrelated gravity anomalies are largely devoid of the long wavelength interfering effects of the terrain gravity and hence provide enhanced constraints for modeling mass variations of the mantle and core. For the Earth, subcrustal interpretations of the terrain-decorrelated anomalies are constrained by radially stratified densities inferred from seismic observations [e.g., 2, 3]. For other differentiated bodies like the Moon, Mars and Venus, seismic soundings are largely lacking so that geochemical and moments-of-inertia considerations must be invoked to constrain the radial density structures in interpreting the terrain-decorrelated free-air anomalies. These anomalies, with frequencies that clearly decrease as the density constrasts deepen, facilitate mapping mass flow patterns related to the thermodynamic state and evolution of the interior.

Method: Gravity drilling was first implemented for mapping lunar intracrustal and subcrustal mass variations using the correlation spectrum between the Lunar Prospector free-air gravity estimates (LP75G) and the terrain-decorrelated anomaly components at 100-km altitude [1]. Our interpretation of the lunar terrain-decorrelated free-air anomaly components is shown in Figure 1. The related correlation spectrum for the Moon in Figure 1B reveals several branches for separating the terrain-decorrelated anomalies into core, mantle and crustal components. For example, the steepest branch (marked by the red shaded triangle) identifies the terrain-decorrelated components that are positively correlated with the free-air anomalies up through spherical harmonic degree 7 that may be interpreted for possible undulations of the lunar core-mantle boundary. Similarly, the two middle branches of the correlation spectrum for the anomaly components from degrees 8 through 12 (orange shaded triangle) and degrees 13 through 24 (green shaded triangle) can be related to density undulations of the middle, and upper mantle, respectively. Furthermore, the relatively flat branch for the anomaly components above degree 25 (grey shaded trapezoid) can reflect the effects of uncompensated crustal density contrasts.

These interpretations of the terrain-decorrelated anomalies can be readily tested against standard geological models of the lunar interior by inversions of the extracted crustal and subcrustal components. Similar modeling of terrain-decorrelated anomalies using inferred radial density profiles of the Earth, Mars, and Venus reveals estimates of the related core-mantle boundaries and undulations of stratified mantle components that reflect mass flow patterns to help explain the development of surface tectonic features.

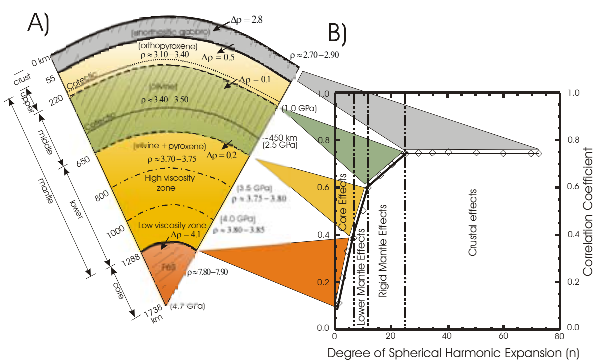

Figure 1. Geologic framework for interpreting lunar terrain-decorrelated freee-air gravity anomalies. A) radial density contrast profile generalized from geochemical analyses of returned samples and moment-of-interia models. B) Correlation spectrum between the terrain-decorrelated and free-air gravity anomalies.

Results: Inversions of the lunar subcrustal anomalies inferred boundary undulations of the lunar core-mantle boundary, asthenosphere-lithopshere, and middle-upper mantle during bombardment time. The elevated core beneath the Procellurm basin is consistent with the uplifting effects of the Imbrium impacts and the development of the great lunar hotspot [4]. Topographic undulations inferred for the lower and middle mantle reflect a dichotomized thermal evolution of the lunar near-and farside. Our results further suggests that on the nearside, a relatively thinner and hotter lithopshere developed by mantle convection which facilitated the diapiric rise of magma and mare flooding of basins. Viscous entrainment of lower density material into the lower mantle on the farside developed a thicker and cooler lithopshere that may also have restricted basin flooding.

For Mars, the terrain-decorrelated anomaly components that are correlative with GMM-2B components up through spherical harmonic degree 4 were taken to reflect mostly density variations of the core. These anomaly estimates may provide important new insight on the poorly understood properties of the Martian core. Similarly, the terrain-decorrelated free-air anomalies from degree 5 through 12, 13 through 17, and 18 through 30, respectively, were taken to broadly characterize lower, middle and upper mantle density variations. These estimates seem to indicate prominent density contrasts that may reflect mass flow within the mantle involved with the development of major basins, volcanoes, and other poorly understood tectonic features of Mars. The residual terrain-decorrelated free-air anomaly correlated with GMM-2B components above degree 30 were taken to largely reflect the effects of intracrustal density contrasts that impose near-surface constraints on the poorly understood Martian crust. These results will be used to test among other things the degree to which the martian hemispheric geologic dichotomy may not be strongly expressed in the subcrust [5].

Our test of this approach for the Earth was restricted to the Antarctic where we were able to resolve only a partial correlation spectrum between the terrain-decorrelated and free-air anomalies at satellite altitudes. Specifically, we obtained a relatively well defined branch for developing core-mantle boundary estimates that are regionally correlated with seismic estimates. These results suggest that East Antarctica between the Gamburtsev and Transantarctic Mountains may be relatively cool to the core.

We are currently extending these results to global gravity analysis for the Earth. We are also working up a gravity probe of Venus to compare with our results for the Moon, Mars, and Earth.

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